Dr. Joe A. Edmisten
Third Quarterly Report to NASA
Contract No. NAS 9-11870

The main efforts of the University of West Florida NASA research team continue to center around the four major health problems of the USA that can be approached through remote sensing. These are Rocky Mountain Spotted Fever, Encephalitis, Malaria, and Red Tides. Attempts are being made to locate the logical agencies to conduct projects to test the possibility of the remote sensing of these and other human health problems. Descriptions of these agencies along with suggested test projects will be presented in our final report.

In addition to the in-depth reports on the above four major health problems, our team has searched the literature in attempts to ascertain if remote sensing might be applied to the detection and/or prevention of other human diseases. Toward that end, we have considered the diseases listed in: "The Control of Communicable Diseases in Man" by Abram S. Benenson. We have also utilized other current NASA work in the form of the University of Texas final report on Contract # NAS 9-11522.

In that report the following list of diseases were reported as unlikely prospects for remote sensing applications:

Table I. Diseases listed in Control of Communicable Diseases in Man, APHA, but eliminated as unlikely prospects for remote sensing applications.

Actinomycosis	Brucellosis	Chancroid
Angiostrongylosis	Candidiasis	Chickenpox
Arbovirus	Capillariasis	Conjunctivitis
Balantidiasis	Carditis, viral	Cytomegalic inclusion
Bartonellosis	Cat-scratch fever	Dermatophytosis

Diarrhea
Diphyllobothriasis
Dracontiasis
Enterobiasis
Fcod poisoning
Gonococcal disease
Hydatidosis
Influenza
Keratoconjunctivitis
Larva migrans
Leproxy
Listerisois
Lymphocytic choriomengitis
Lymphogranuloma venereum
Measles
Meningitis, aseptic
Meningitis, meningococcal
Mononucleosis infectious
Mucomycosis
Mumps
Mycetoma
Nocardiosis
Paragonimiasis
Paratyphoid
Pediculosis
Pinta
Pleurodynia
Granuloma inguinaie
Hepatitis, viral
Herpangina
Herpes
Rabies
Rat-bite fever [2.]
Relapsing fever
Respiratory disease, viral
Rheumatic fever
Rickettsialpox [2.]
Rubella
Salmonellosis
Scabies
Smallpox
Sporotrichosis
Staphlococcal disease
Streptococcal disease
Syphilis
Pneumonia
Poliomyelitis
Psittacosis
Q fever
Taeniasis
Tetanus
Toxoplasmosis
Trachoma
Trichinosis
Trichomoniasis
Tuberculosis
Tularemia[3.]
Typhus, murine [2.]
Typhus, epidemic
Whooping cough
Wolhynian fever
Yaws

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1. There are over 200 arboviruses now described in varying detail; but for the vast majority of these the ecological data are far too scant to permit comment. Those which are considered further are listed in Table 13.

2. Presumably a number of rat-borne diseases of urban areas are related to numbers of rodents, which in turn may be related to housing quality. However, the relationship appears to be too tenuous to permit analysis.

3. Partially vector and water-borne, primarily contact.

Our findings reenforce those of the University of Texas team with one minor exception. We feel that during rabies outbreaks, remote sensing can be of great value in the detection and control of foxes serving as the wild reservoir of the disease. The use of imagery indicator vegetation types (habitat) along with heat detecting infrared devices could be used to locate, trap and control fox and racoon populations during such outbreaks.

The posible detection of various intestinal worms (helminths) by remote sensing mentioned in the Texas report is questioned by our search

of the literature but should be examined by a small test project with special emphasis upon the detection of man's sanitation practices.

The case for the use of remote sensing in the detection and prevention of anthrax would appear to be even stronger than suspected by the University of Texas team. In addition to the kinds of soil types and temperatures mentioned, there are, in each region of this country, sets of indicator plants that enable one to locate calcareous soils and hence the optimum pH of 7 or 8 associated with incubation areas for Bacillus anthracus. The cabbage palm is such a species for Central Florida and Red Cedar for Tennessee. We strongly suggest an expanded NASA-NDCD project in the Ascension Parish in Louisiana and a similar new project in Central Florida.

The University of West Florida team feels that the remote sensing of coccidiomycosis holds very little promise. Our search of the botanical literature indicates little if any association of the causal fungus with Larrea tridentata. Further the crecsote bush is too common and widespread to be of great value.

There is strong evidence that remote sensing can be applied to the Histoplasmosis problem. In addition to detection of birds and their roosts as mentioned in the Texas report, the detection of Histoplasmosis bearing caves in Puerto Rico can be routine. A project to map the distribution of such caves in Northwest Puerto Rico should be investigated.

Of the nine water-borne diseases considered in the Texas report, only one, Schistosomiasis appears to merit the support of a test project. The eight others are either not associated with remotely sense-

able objectsor they are not important enough in the United States to warrant current concern.

Table II.

Disease		
Amebiasis	Giardiasis	Shigellosis
Cholera	Fascioliasis	Typhoid fever
Diarrhea (various)	Chlonorchiasis	Schistosomiasis

Five years of personal field experience in Puerto Rico, St. Thomas and the American tropics, cause me to endorse the concept that the host snail for Schistosomiasis can be associated with the remotely sensed plant Caladium. In addition to the remote sensing of this plant and the drainage patterns where it is found, it would be of great value to remotely ascertain man's contact with the water. The use of IR and color photography would economically relate man's use of the waters for (1) recreation, (2) washing garments, (3) transportation (crossings), (4) and the general proximity of his dwellings. It is strongly suggested that NASA support continued efforts in Puerto Rico since this d sease could and probably will manifest itself in Florida sooner or later if control in Puerto Rico is not achieved.

The Texas report considered the following zoonotic diseases as possible candidates to be approached by remote sensing.

Table III. Some Diseases of Rodents Transmissible to Man

Disease	Mode of Transmission
South American Hemorrhagic Fevers (Tacaribe and Junin viruses)	Rodent excreta
Korean Hemorrhagic Fever	Unknown
Leptospirosis	Animal excreta in water
Meliodosis	Animal excreta in soil
Plague	Fleas

In our consideration of this category of diseases, the search of literature indicated that only Leptospirosis currently is approachable via remote sensing or is of current importance in the U.S. to warrant a test project. We find no consistent indicator plants nor vegetation types associated with rodents and other mammals capable of carrying Leptospirosis. The logical approach would appear to use remote sensing to ascertain the spatial location of lakes and farm ponds (used for swimming) in relation to potentially infectious animals. An aerial survey for such spatial arrangements within drainage patterns might help prevent many infections.

Of the 17 arthropod-borne diseases considered by the University of Texas group, only 10 appear to be serious enough in the US and territories and are approachable through remote sensing. Five of the 10 are various forms of encephalitis and are covered in detail by NASA fellow, Ed Meyers. Our recent field trips to the VEE sites in the Everglades Hammocks will be used to help interpret Dr. Sudia's findings and utilize more fully the color and IR aerial photography of these well documented sites. These interpretations and detailed recommendations will be presented in our final report.

Rocky Mountain spotted fever represents an exciting possibility for the use of remote sensing in finding areas where tick bearing rodents can be found by their association with old field succession vegetation types. The proximity of people and their suburbian dogs to such possible disease zones can be easily ascertained. This theme is developed more fully in the body of this report by NASA fellow, Rob Mattlin.

Although the U.S. is not currently considered malarious, it has all the ingredients to become so overnight. The Texas report reflects the expertise of Dr. John E. Scanlon in the area of malaria. Our finding reconfirms his and attempts to expand upon them with recommendations for a test project in the TVA system. This section is developed more fully by NASA fellow Fred Pitts.

Trypanosomiasis in Panama appears to be serious enough to warrant attention. The vector (Reduviidae) is consistently associated with sub-standard housing as established in the University of Texas report. The use of remote sensing in the location and treatment of such sites is apparent.

The University of West Florida team findings support the Texas findings for Onchocariasis and yellow fever. In the case of yellow fever, it is further suggested that the remote sensing of monkey populations in tree tops could be used to help delineate host areas of the jungle type.

Stomoxys calcitrans known in the Southeastern United States as dog fly and other parts of the world as the stable fly represents a readily achievable control task via remote sensing. Although this biting, blood-sucking fly has not been directly associated with the transmission of human disease, it is probable that several diseases could be spread by it since it exhibits great longevity (for an insect) and travels great distances. Aside from the above health reasons for the need for control of the dog fly there are great social and economic reasons for possible NASA concern in this case.

The dog fly effectively closes the beaches of West Florida and the mid-gulf region one-to-two months prematurely with its painful bite. During late August or September, the dog flies emerge in great swarms from windrows of rotting turtle grass around the 1000's of miles of bays, sounds and inlets of the panhandle section of Florida. During the 1940's, military actions in the mid-gulf section were greatly curtailed or stopped by these blood-sucking insects.

Currently, a new National Gulf Island Park is being organized in the exact region where the dog fly problem is most severe. While the problem was partially alleviated in the 1940's and 50's by the heavy use of DDT, we can expect no chemical relief by the use of chlorinated hydrocarbons in these ecological times.

The most readily feasible means of controlling this economic pest and potential spreader of disease is the mechanical (removable or treatment) of the piles of rotting Thallasia, (turtle grass). NASA and remote sensing enter the picture here with the ability to locate and map the Thallasia beds during the maximum growing season and predict where the pile (breeding sites) will occur and finally, the actual location of them for their economical, mechanical romoval and/or treatment.

In addition to the above classical disease problems, we continue in our efforts to utilize NASA expertise in the Red Tide problem which is covered in detail in the body of this report.

Fred Pitts
Third Quarterly Report to NASA
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MALARIA

The second quarterly report on malaria and its potential to be monitored by remote sensing devices indicated that the principal consideration is that of vegetation types (not taxa). Russell, et al. (1963) and Hall (1971) have reiterated the importance of the plant-air-water interface which has been called the "intersection line" by Hess and Hall (1943).

Also previously mentioned was that the principal vectors in North America are Anopheles Quadrimaculatus, A. freeborni, and A. albimanus, (Russell, et al. 1963). Several points of interest in mosquito binomics, which may be of importance in the final analysis, are provided herein and will be referred to later.

The EGG

According to Hall (1971a), areas of water with the "surface broken-up into numerous quiet cells" are favorable for ovipositing. Russell et al. (1963) stated that all Anopheline species lay their eggs, numbering up to 350 depending on the species, at night or just before sunrise. They are either singly deposited or in loose groups on the water suface; and often, in the case of A. quadrimaculatus, without regard for the presence of chemicals, extremes of pH, presence of vegetation, etc. A blood-meal is often, but not always, necessary for the production of eggs. The eggs of A. quadrimaculatus have been shown to respond drastically to temperature, such that

development can not be completed below 53^{o} F. On the other hand, eggs of other species may not be as susceptible to temperature changes.

The Larva

The larvae of Anopheline species may survive for a short time on moist surfaces, but essentially require an aquatic environment. There are several factors important in larval development, which include flora, fauna, water movement and temperature, sunlight, shade, chemical composition, turbidity, and contaminants (Russell et al. 1963).

Flora

A. quadrimaculatus prefers floating vegetation such as Azolla, Lemna, and waterlilly (Russell et al. 1963). Darsie and Springer (1957) reported it commonly in association with swampdock, cattail, rosemallow, phragmites, coontail (ceratophyllum demersum), duckweed, pondweeds, algae, switchgrass, and wild millet. Hall (1971b) found that anopheline density should be greater with flexuous, submersed and floating-mat types of vegetation, but pointed out that submersed varieties became important only when the plants reached and intersected with the water surface. He found that intermediate production occurred or should occur with free-floating and erect leafy types, and the lowest production should occur in the presence of erect-naked, floating leaf, and bottomland forests of water-tolerant woody species. Productivity is encouraged by the presence of significant quantities of flotage and discouraged by clean vegetation-free water. A. albimanus is commonly found in association with Pistia stratiotes in quiet water, and often uses artifical containers, animal hoof-prints, tree leaves, and the like; and in lakes and slow rivers with

matted vegetation A. freeborni, according to Russell et al. (1963), prefers fresh, clear seepage, irrigation ditches, certain contained streams, etc.

Fauna

The fauna is important in consideration of natural enemies of larvae, such as the larvivorous fish Gambusia, certain amphibians, and beetles of the family Hydrophilidae.

Water movement

Some species are found in gently moving water, but most are highly vulnerable to water velocity. For example, A. quadrimaculatus is found ordinarily in still water which encourages ovipositing.

Sunlight and Shade

According to Russell et al. (1963), A. freeborni is strongly heliophilic (sun-loving), while others prefer some shading. This feature is probably related more to adult ovipositing behavior than to larval tropisms.

Temperature

A. quadrimaculatus thrives best in larval stages at about 88° F. Anophelines are generally best adapted to warmer temperatures as their tropical distribution suggests.

Surface Tension

The larvae of most mosquitoes depend upon surface tension in order to stay at the surface where they breathe. A. quadrimaculatus has been shown to change its feeding habits to some extent in response to changes in surface tension, such that it feeds interfacially during high tension or by the "eddy mechanism" during reduced tension (Russell et al. 1963). Surface tension is reduced by the input of certain insecticides, detergents, etc.

Hydrogen-Ion Concentration

The larvae of most species can tolerate a rather wide range of pH; but according to Russell et al. (1963), A. quadrimaculatus prefers an intermediate pH range. Darsie and Springer (1957) found the species in pH as low as 6.2, as high as 9.3 and with a mean of 7.2 in impounded waters in Delaware.

Salinity

A. albimanus has been found abundantly in lagoons with 15-25 per cent sea-water concentrations. Darsie and Springer (1957) considered A. quadrimaculatus to be a permanent-water, fresh-water species. They reported A. albimanus as having a low salinity tolerance.

Pollution

Pollution is important in that it can effect surface tension, oxygen content, toxicity, etc., as it relates not only to larval growth but to the vegetation types as well. Nevertheless, the effects of pollution are variable and relative.

Turbidity

Siltation is probably less important in turbidity than the currents themselves which serve to move the larvae into unfavorable environmental conditions.

Larval Food

Larvae eat principally unicellular algae, flagellates, ciliates, and other floating life.

The Pupa

This stage lasts for a number of hours ranging from 38 to 309, depending on the temperature, with the .nimum temperature at about 53° F (Russell et al., 1963). An increase in temperature yields a decrease in duration of the pupal stage. Prior to emergence, the pupae undergo changes which are critical to emergence. Air occurs between the pupal skin and the imago. The pupae float more highly, then over a period of minutes, the skin ruptures, and the insect rests on the skin for a time and finally flies free.

The Adult

Toward nightfall they swarm and pair-off, then the cycle is repeated. *A. albimanus* have been known to reach three to four miles from their breeding areas, while *A. quadrimaculatus* may transmit malaria two or three miles away. *A. freeborni* engages in a post-hibernation flight in early spring and may fly as much as eight miles.

Males are fairly short lived. The life span may range from a few days in the tropics to one or two months in cooler zones.

A. albimanus is generally more abundant during rainy seasons. Darsie and Springer (1957) found in Delaware *A. quadrimaculatus* regularly from late June and early July through September or early October with the greatest density from July to September.

Now having considered mosquitobinomics, it might be useful to reconsider the overall picture, i.e. the relationship between vegetation types and other ecological factors as they mutually relate to remote sensing potential.

Since eradication programs are most effectively launched against the larval forms of mosquitoes, it is not necessary to consider adult

habitat. Further, since A. quadrimaculatus is the principal vector in this country, it might be reasonable to disregard the incidential vectors, A. freeborni and A. albimanus. A density map (attached), provided by the CDC in Atlanta, is furnished here for reference, showing the relative densities and distribution of the three vectors.

The foremost consideration in the case of A. quadrimaculatus is that of the intersection line, the air-water-plant interface. It is established that slowly moving or still water with an abundance of vegetation is required for the production of the species. Smith (1907) outlined three classes of marshes: (1) that covered at every mean tide --- not a hazardous productive zone; (2) that rarely covered by ordinary tides but low enough that some high tides will cover entirely --- not a hazardous zone; (3) that entirely above mean high tide with abundant vegetation. Some tidal input which trickles through the grasses --- prolific breeding here. This classification is basically agreed upon by Griffitts (1929), DeVido (1936), Connell (1940) and Kin et al. (1944) A. quadrimaculatus has a low tolerance for saline input and is considered a fresh-water species.

In the final report, there will be a chart provided indicating the limits of the parameters in question which effect anopheline production and a suggested method of remote sensing.

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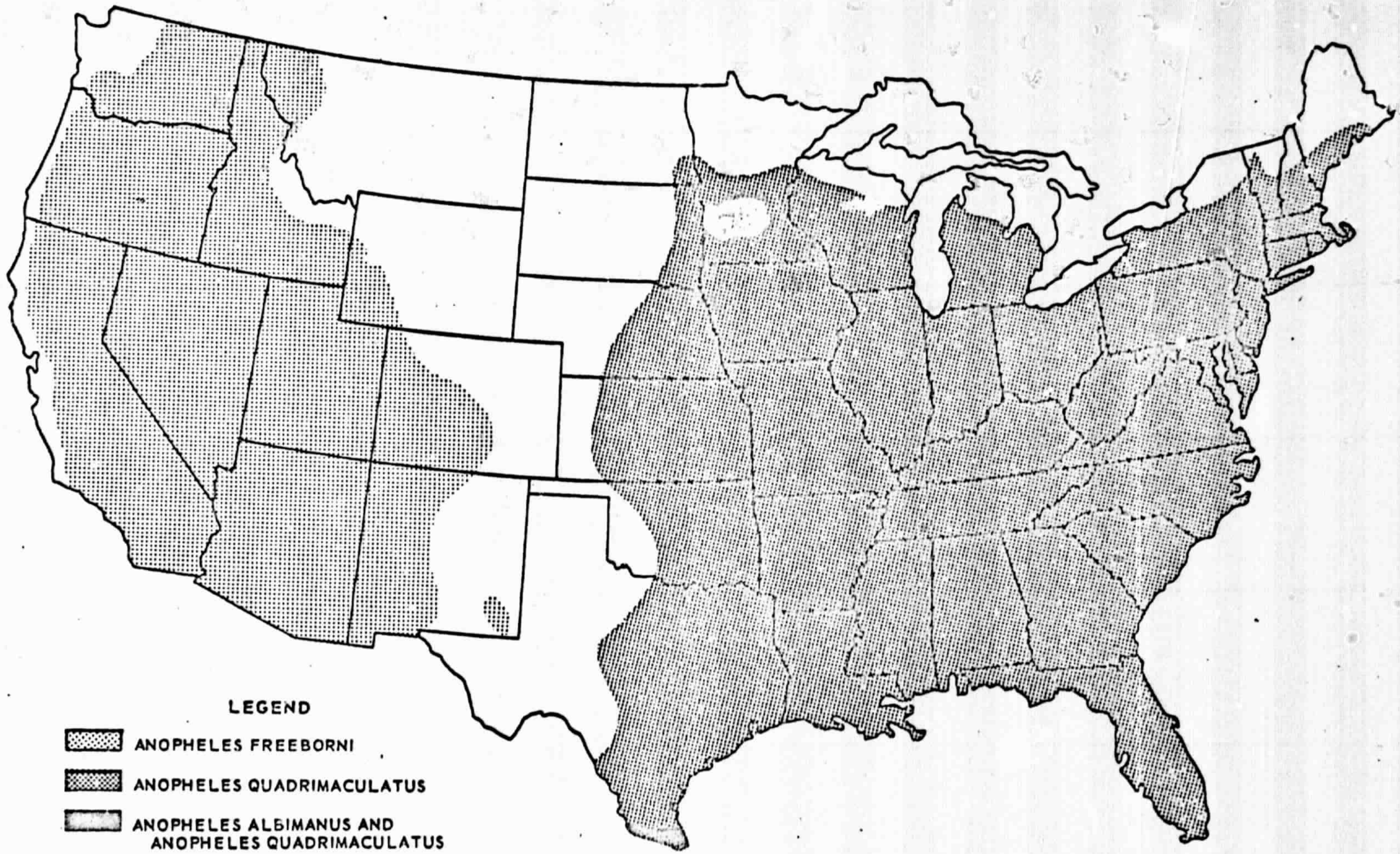

DISTRIBUTION OF MALARIA VECTORS IN THE U. S.
1966

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE, Communicable Disease Center, Training Branch, Atlanta, Georgia 30333

Sandra F. Miller
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REMOTE SENSING OF RED TIDE

Red Tide as an environmental and health problem has been documented in terms of historical and scientific literature. The environmental factors which contribute to Red Tide outbreaks have been discussed in detail, especially those with remote sensing applicability. The purpose now becomes one of determining which factors are feasible and most important to monitor. A matrix is being compiled which presents the environmental problem, resolution desired, most feasible sensors, the range and resolution of these sensors, and a recommended sensor for each environmental parameter. This completed matrix will be included in the final report to NASA. We also hope to promote the project into existance by supporting the most probable agency to do this research.

The Florida Department of Natural Resources has been recommended as the most capable agency to do the ground-truth research and direct remote sensing studies of the Red Tide problem. The head of the Bureau of Marine Science and Technology, Robert M. Ingle, has already expressed written interest in this project in his March 31st, 1972 letter to NASA. The qualifications of this agency and the interest expressed recommend it most highly for this project.

INTRODUCTION

The application of remote sensing to the study of Red Tide is an exciting proposition. Remote sensing of the environment has proven extremely valuable and successful. Applications of remote sensing cap-

abilities to fishery and oceanography problems have proven the vast amount of information attainable and resolution possible in such work. It seems possible and feasible to apply remote sensing to every aspect of the Red Tide problem.

The task before remote sensing studies is the detection of environmental parameters leading to the conditions favorable for a Red Tide. A list of the important parameters with probable remote sensing application seems appropriate.

Oceanographic and normal weather parameters to be monitored:

1. Ocean state
2. Wind velocity and direction
3. Temperature (air and water)
4. Salinity
5. Light intensity
6. Rainfall in areas drained by local rivers

Other environmental parameters associated with Red Tide:

1. With heavy rainfall, tanic acids and humic acids discolor river water and make their way to the Gulf. Sensing of this color change and the progress of river water containing these iron chelating substances toward the Gulf is important. Also an attempt should be made to correlate river color with ground truth - iron content of the water in the rivers.
2. When heavy rainfall increases the freshwater flow into an estuary, the estuary can in turn spill over with less saline water. The result is a visible plume of water entering the Gulf. This water is often of a different color and it would contain suspended particulate matter which could be remotely sensed.

3. When two water masses of different compositions meet, a type of current or convergence is produced; the wind factor is also involved. Red Tide outbreaks usually occur along these convergences in wind rows or patches, so their presence should be monitored.

4. It is possible to detect chlorophyll concentration with remote sensing (Clarke and Ewing, 1970). Increases in phytoplankton with time or changes in concentration in space are important in the Red Tide problem. Also, the detection of a different organism in bloom proportions, <u>Oscillatoria erythraea,</u> preceeding blooms of <u>Gymnodinium</u> <u>breve</u> is extremely important in Red Tide studies.

5. Another interesting aspect of phytoplankton populations in high concentration is their bioluminescent qualities. <u>G. breve</u> has displayed this character. Ryther (1955) found that the bioluminescence was displayed by phytoplankton at the greatest intensity at midnight, and the least intensity at noon producing a dial cycle. The luminescence can be remotely sensed - and the best time to detect this quality would be at midnight. If luminous intensities measured by remote sensing (satellite or aircraft) could be correlated with concentration of <u>Gymnodinium</u> <u>breve</u> cells, this would be an extremely effective method.

6. The precise concentration of <u>G.</u> <u>breve</u> detectable by remote sensing would be of immense value in determining the extent

of a bloom and whether or not toxic concentrations have been reached. Detecting G. breve blooms before harmful concentrations have developed could be the vital step toward control of Red Tide. Control of Red Tide must be possible before toxic conditions are present, since destruction of the toxic population merely releases the toxins at an accelerated rate rather than preventing the damage caused by Red Tide.

7. Ray (1971) reports that since PSP (paralytic shellfish poisoning) (and also the less-toxic-to-humans shellfish poisoning caused by G. breve) is directly related to the occurrence of toxic dinoflagellates (Sommer et al., 1937; Needler, 1949; Prakash, 1963; Wood, 1968), the systematic search for dinoflagellate blooms as indicated by discolored water (Red Tides or redwater) and plankton sampling for toxic dinoflagellates may be used to determine where and when poisonous shellfish are likely to occur. This is precisely what remote sensing can accomplish, while attempting at the same time to develop Red Tide predictive ability.

8. Prediction of Red Tide outbreaks is one of the purposes confronting remote sensing studies. After prediction then control can be attempted.

NASA has developed remote sensing to a state-of-the-art which boarders on amazing. All aspects of the Red Tide problem can be remotely sensed with present resources, either from satellites or aircraft. The application of remote sensing to Red Tide studies is a new proposition, however, with ground-truth research and remote sensing sur-

veillance of the problem, it seems hopeful that the many questions still unanswered concerning this problem will be answered in the near future. A summary of the applications and imagery sensing devices seems appropriate. From these, the most efficient combination of devices coupled with the most effective altitude, distance to be surveyed, and times to increase the frequency of surveillance, a tentative proposal to apply remote sensing and ground truth to study Red Tide can be offered.

APPLICATIONS/IMAGERY SENSING DEVICES (gathered from Remote Sensing of Earth Resources - NASA, September 1970, and Third Annual Earth Resources Program Review: Vol. III, Hydrology and Oceanography, NASA, Houston, Texas, December 1970.)

1. Ocean state........................	Microwave radiometers Radar backscatter (experimental) Laser electro-optical instruments
2. Wind velocity and direction........................	Microwave radiometers Laser instrumentation
3. Temperature (air and water)........	Infrared radiometry IR imagery
4. Salinity........................	Microwave radiometry (experimental)
5. Light intensity (incident and reflected solar radiation)...........	Spectroradiometric equipment Four lens multispectral camera
6. Rainfall........................	*(Weather bureau information)
7. Ocean color (chlorophyli)..........	7 - 10 can all be detected using color IR photography
8. Turbidity and nutrient pollution	
9. River flow and outflow	
10. River color	

In general:

1. Accuracy (resolution) increases with decreased altitude.
2. Aircraft and satellites carry essentially the same types of sensors.
3. Information required would necessitate Flight Profiles below 10,000 feet. The most accurate temperatures (surface) have been obtained from an altitude of 1000 feet.
4. Color photography can penetrate up to 15 feet of water for practical applications.

The following table is from a University of West Florida, Aeronautical Systems, Special Student Report, 1971. SOS: Satellite Oceanographic Sensing, p. 1-9.

Table 1.3 - OCEANOGRAPHIC SCIENTIFIC DATA REQUIREMENTS

Data Form	Resolution	Range	Spatial Resolution
Surface Temperature	1° C	0 to 25° C	3 N. M.
Surface Salinity	0.5 gm/kg H_2O	10 to 40	10 N. M.
Surface Roughness (small wavelengths)	0.3 m.	0 to 20 m.	$\frac{1}{4}$ N. M.
Windspeed	1 m/sec	0 to 50 m/sec	
Surface Roughness (wavelength greater than 1 km)	0.3 m.	0 to 40 m.	1 N. M.
Color Spectra	0.1 micron	0.3 to 2.0 microns	1 N. M.

Whenever resolution is not sacrificed, the least complicated equipment should be used, and whenever the same equipment can gather several sets of data on different parameters, this instrument is desirable. It would seem from the review of the available resources and capabilities, that an aircraft equiped with microwave radiometers (a type of side looking radar), several cameras with the appropriate film, lens and filter combinations for the data in question, could feasibly and efficiently monitor the environmental, oceanographic and weather para-

meters for Red Tide studies. Perhaps the most efficient approach would be to use the less resolution of satellites during times of the year when monitoring is merely routine. When certain ground-truth data reveal that conditions warrant more frequent and better resolved surveillance, then aircraft could take over. The area which should be monitored extends from Apalachicola, Florida to the Florida Keys, with special reference between Tampa and Ft. Meyers, Florida. Ground truth should monitor iron content and iron chelator concentration in the rivers which feed Tampa Bay and Charlotte Harbor and in the north, Apalachicola Bay. Some correlation between river color from remote sensing and the presence and concentration of tanic acids and humic acids should be attempted. Salinity and freshwater flow should be monitored in the estuaries and in the adjacent Gulf waters. The times and locations of convergences along with appropriate wind direction and velocity should be noted. Species composition and numbers of phytoplankton populations should be monitored at precise times of aircraft surveillance. Since light attenuation can be attributed to the phytoplankton organisms during times of high standing crops, the backscattered light in the form of spectrum analysis, can reveal the materials (phytoplankton) suspended in the water. Chlorophyll has a recognizable spectral signature. Clark and Ewing (1970) have demonstrated the feasibility and utility of this remote sensing technique to detect chlorophyll over the range of concentrations characteristic of the open ocean. Spectra have been obtained from water masses with concentrations up to 3 mg chlor/m^3 and higher values could easily be recorded. In their study over an

area of a mile between the Georges Banks and the Sargasso Sea, the chlorophyll concentration changed from 0.3 to 0.1 mg/m^3 and the temperature from 18°C. to 23°C. The transition was clearly visible at altitudes ranging from 500 ft. to 10,000 ft. A consideration of transparency, bioluminescence and plankton is presented by Clarke (1965). It then seems possible to attempt correlation of these remote sensing measurements with actual phytoplankton concentrations determined from ground-truth data. When resolution is determined then attempts can be made to correlate differences in the population (<u>Oscillatoria</u> to <u>Gymnodinium</u>), or changes in the <u>G</u>. <u>breve</u> concentration from non-toxic to toxic levels. These applications of remote sensing are possible and important.

Time is an important factor in this type of research. General times can be dictated to begin remote sensing and ground truth, but environmental factors will indicate more precise times. So at present it suffices to say that satellite surveillance could transmit information on weather and oceanographic data along with some ocean color information throughout the winter months. As rainfall and hurricane information suggests, more intensive surveillance should begin in the spring and summer. Since Red Tide outbreaks occur more often in the very late summer or early fall and continue into October or November, depending upon cold waves and other conditions, these times suggest the most intense surveillance and ground truth. Even in years when Red Tides do not occur, valuable information can be obtained. A study of this magnitude should be carried out for a period of several years (10 years for an estimate), and developed

until precise information can be determined from remote sensing alone on the prediction of Red Tide. Even if ultimate control is not possible, the prediction of Red Tide outbreaks by these methods, will be of extreme value.

Bibliography: Please see references in Second Quarterly report to NASA.

Ed Meyer
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ENCEPHALITIS

In the first and second quarterly reports, emphasis was placed on the vector ecology of encephalitis. This third quarterly report deals with the equine arbovirus itself in order to give a deeper understanding into the problems of its control.

Clinical and Pathologic Features

The equine viruses (WEE, VEE, EEE) are agents which are serologically different from each other. However, one of the essential points of similarity among the three is that ordinarily the encephalitis in man is unusual or accidential. The usual form of infection being, at least with WEE and VEE, asymptomatic, abortive, or systemic. Indeed, VEE is almost always a systemic disorder, often resembling in its clinical picture influenza or dengue, although horses may show encephalitis. For WEE and EEE its order of susceptibility is probably first woodland animals (especially birds), then horses and last human beings.

Although the clinical features of established cases of encephalitis due to infection with EEE and WEE viruses are indistinguishable, the fatality rate following symptomatic infection with EEE approaches 80%, while it ranges between .5% and 15% for WEE infection. In California, about 27% of WEE cases occurred in infants iess than one year of age, but in New Jersey, EEE virsus affected all age groups relatively evenly (Rhodes and Van Rooyen, 1968).

Antibody surveys for Group A, arbor viruses, made under conditions favorable for proper interpretation despite cross-reaction, reveal that large numbers of the general population in endemic and epidemic areas develop clinically inapparent infections. This is true with the virus of EEE with which, in the earlier surveys, there seems to be an increasing number of reports of persons that have antibody in the absence of recognizable encephalitis.

Epidemiology

During the past three decades large outbreaks of encephalitis have occurred among human beings and horses in many parts of North America. For reasons of geography, the two causative viruses were desiginated eastern and western equine encephalomyilites, following isolation from the central nervous system of horses. In general, cases of EEE occur principally along the Atlantic Coast of the U.S. from New Hampshire to Texas, but cases have occurred as far inland as Wisconsin. Infection with EEE viruses has also been encountered in the Caribbean and Central and South America. In contrast, human infection of WEE virus have occurred principally in states west of the Mississippi River and in the Canadian prairie provinces, Central and South America, and the Caribbean. However, along the eastern seaboard of the USA, increasing evidence of its spread has been obtained with the isolation of WEE virus in Massachusetts, New Jersey, and Florida.

Venezuela equine encephalitis has occurred in Venezuela, Brazil, Columbia, Ecuador, Mexico, Panama, Trinidad, and most recently southwestern United States.

In the US the disease prevails chiefly from early June to September, with the peak months being August and September.

Properties of the Viruses

Electron microscopic studies demonstrate that the viral particle consists of a .30 mμ core separated by a zone of lesser density from a sharply defined peripheral membrane; over-all diameter is 45- 48 mμ. Percursor particles, 22 mμ in diameter, differentiate at sites close to membranes bordering cytoplasmic vacuoles and either pass into the lumen of the vacuole or are extruded through the surface of the cell wall, acquiring a coat and membrane meanwhile. Degeneration of the host cell may or may not occur during release of virus (Rhodes and Van Rooyen, 1968).

The viruses multiply readily after intracerebral or peripheral inoculation of suckling or weaned mice, causing encephalitis which terminated fatally within 184 days after injection, depending on the dose. Guinea pigs develop fatal encephalitis, but rabbits usually develop inapparent infection with production antibody following peripheral inoculation. Fatal infections may occur in horses, but cows usually do not develop symptoms following mosquito bites.

Domestic fowls and most species of wild birds develop symtomless viremia at titers sufficient to infect *Aedes aegypti* and *A. triseriatus* mosquitoes. Viremia is first detected one day after being bitten by infected *A. aegypti* and persists 4 to 5 days. Subsequently, antibody can be detected in sera by neutralization and antilemagglutinin tests.

Experimental Infection - Host Range

One of the distinguishing characteristics of the anthropod-borne viruses is that of a fairly wide host range. By definition, these viruses are capable of infecting both invertebrates and vertebrates. Among the vertebrates, many species of mammals and birds may be infected with these viruses. However, each virus tends to have one class that will furnish the more important hosts (Kissling, 1958).

WEE

The western virus has a very wide host range. In nature, human beings, horses and mules have shown signs of infection, and the virus has been isolated, in addition, from squirrels, deer, pigs, and birds. The experimental infection with signs of illness can be induced by intracerebral inoculation in albino mice, hamsters, rats, guinea pigs, domestic and wild rabbits, monkeys, squirrels, cotten rats, kangaroo rats, wood rats, wild mice, young dogs, deer, pigs, gophers, calves, goats, prairie chickens, and pigeons. Sheep and cats are resistant.

Hammon et al. (1951) found that viremia was present in English sparrows, house finches, tricolored red-winged blackbirds, and white-crowned sparrows following subcutaneous inoculation of virus. The western virus was recovered from some individuals as late as 9 and 10 days after inoculation. Most recoveries of virus were made during the first four days after inoculation, with the maximum titers of 10^4 and 10^6 LD_{50} occurring during the first two days. Similar results were found with other birds by (Kissling et al. 1957)

and (Kaplan, Winn, and Palmer 1955). Domestic foul have been shown to circulate sufficient virus in their blood to allow infection of Culex tarsalis (Hammon & Reeves, 1943).

In the case of WEE virus, it appears that birds are the primary hosts of the virus, wild birds being especially incriminated. Domestic poultry may play a secondary role, depending upon the vectors accessibility to them.

EEE

Horses have been found to circulate EEE virus in their blood after experimental infection (Giltner & Shahon, 1936). The virus appears with a fair degree of regularity, but its presence is of short duration, usually for one to three days only. The maximum virus titers observed have ranged from $10^{0.5}$ to $10^{5.2}$ LD_{50}. Horse-to-horse transmission through the bite of mosquitoes has been shown experimentally (Sudia et al., 1956).

Investigations on avian hosts (Kissling, 1954), have demonstrated that birds differ in their response to infection with EEE virus in several significant ways. In general, the small marsh birds and song birds (red-winged blackbird, cardinal, sparrow) manifest exceptionally high blood virus titers but the majority succumb to a culminating disease within two to three days. Other species (ibis, egret, purple grockle) develop few or no signs of infection and exhibit a lower viremia range. The virus is present in the blood stream of birds for periods up to about 120 hours, but only for one third to one half of that period is the titer adequate for infection of mosquitoes.

Bird-to-bird transmissions via the bite of mosquitoes were accomplished with relative ease in those birds carrying optimum levels of virus for mosquito infection, but such birds as the ibis and egret usually had insufficient blood virus concentration for infection of the test mosquitoes (Aedes aegypti). Birds with higher virus titers are therefore effective sources of infection although the duration of the infective interval may be rather short due to the rapid and high mortality rate which usually occurs among such birds.

VEE

Venezuelan equine encephalitis virus is one of the arthropod-borne viruses that seem to multiply with greater efficiency in mammals than in birds.

Horses infected experimentally with VEE virus circulate four to six days (Kissling et al., 1956). Maximum blood virus titers were found to range from 10^{4} to $10^{7.5}$ LD_{50}. These high titers were maintained for longer periods of time than were the maximum blood virus titers in horses infected with EEE virus. No difficulty was experienced in infecting certain species of mosquitoes by allowing them to feed upon horses in the viremic stage.

Very little has been done with other species of mammals, but Sudia (1968) has found wild rodents to be the apparent natural hosts of VEE in the Everglades.

Wild birds, especially those native of North America, when infected with VEE virus do not have viremia levels as high or of as long duration as horses (Chamberlain et al., 1956). Birds in

the viremic phase of the disease seldom had sufficient blood virus present to allow mosquito infection. VEE virema periods in these birds rarely exceeded three days.

Interepidemic Survival of Encephalitis

The bird-mosquito-bird cycle source of encephalitis is generally accepted with a mammalian component suspected in certain foci, especially with VEE. Reptiles and amphibians have come into serious consideration and experimentation as possible key elements in the little understood mechanism of overwintering.

Epidemics of these diseases occur irregularly in time and location. In temperate areas, where most epidemics occur, mosquito populations are greatly reduced or absent during winter months. A number of different mechanisms of virus survival have been postulated.

Virus transmission between birds and mosquitoes may persist in small areas of especially favorable habitat where some mosquitoes are active throughout the year. A continual supply of susceptible birds may move into such areas for food or water or by ordinary movement of migratory birds. Migrant birds may then transport viruses from these areas to others favorable for transmission during spring and summer months. Investigations of this mechanism have yielded negative results to date but have been conducted on a scale too small to make an evaluation (Stamn & Newman, 1963).

Survival of these viruses through winter months in hibernating mosquitoes has been shown in at least Culex tarsalis and C. quinquefosciatus (Bellamy et al., 1958). These mosquitoes were

able to transmit WEE by bite after being kept under natural winter temperature three to four months in Kern County, California.

Survival of mosquito-borne viruses in bird mites or in ticks has been suggested. While virus has been isolated from several species of bird mites, it has not been possible to show transmission of the virus by their bite (Reeves et al., 1955, Sulkin et al., 1955, Chamberlain and Sikes, 1955). Syverton and Berry (1941) succeeded in transmitting the disease to animals by means of experimentally infected wood ticks, Dermacentor andersoni, however, there has been no epidemiologic evidence thus far that the tick is an important vector.

Small mammals, including bats, have been investigated to some extent as hosts of overwintering virus. Laboratory studies have confirmed the possibility that this mechanism can operate, but its occurrence of such a cycle in nature has not been demonstrated (Sulkin et al., 1963). Recently, however, evidence has appeared in Colorado, New Jersey, and Florida that small rodents act as hosts for the virus, especially during winter months.

The persistence of virus in some birds, perhaps in a latent form, has been demonstrated by isolation of virus from tissues, including blood, between 55 and 306 days after the initial infection. It has not been demonstrated, however, that sufficient concentration of the virus circulates a second time in birds to infect mosquitoes and re-initiate the natural cycle (Reeves and Hammon, 1962).

The garter snake, Thamnophis ordinoides, develops viremia between three and eight days after being bitten by Culex tarsalis mosquitoes infected with WEE virus. Virus was isolated from the blood of snakes after periods of hibernation for five to six months out of doors with minimum temperatures between -8 and -18° C., followed by a further holding period in the laboratory of 8 to 16 days at 22° C. (Gebhart and Hill, 1960, Thomas and Eklund, 1962). Although virus has not yet been isolated from the blood of naturally infected garter snakes, this experiment suggests that snakes may serve as additional vertebrate reservoirs of encephalitis in regions of North America which undergo extensive freezing dúring winter.

Final Report

The fourth and final report will summarize the important and detectable environmental limitations and associations with VEE, WEE, and EEE mosquito vectors. It will include the comprehensive work on VEE ecology presently being undertaken by Dickerman and his associates in southeastern Mexico.

A suggested study plan will be formulated. This will include the appropriate remote sensing devices and ground-truth data necessary to asses the possibility of using remote sensing for equine encephalitis control in a specific region of the United States.

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ROCKY MOUNTAIN SPOTTED FEVER

INTRODUCTION

Of the rickettsial diseases prevalent in the world today, Rocky Mountain spotted fever, Brill's disease, murine typhus, Q fever, and rickettsial pox are forms presently found within the United States. Of these five, Rocky Mountain spotted fever is the only one causing a significant mortality, accounting for over 90% of the total for these five rickettsial diseases. Though the reported incidence of Rocky Mountain spotted fever is down from the high of almost 600 cases annually in 1946 and 1947 to an average of less than 300 cases annually for the years between 1954 and 1964, the disease is again on an upward trend with 498 reported cases in 1969.

Further, the name Rocky Mountain spotted fever itself tends to be misleading, in that in recent years there has been more cases reported not from Rocky Mountain states, but rather from the Southern and Southeastern states of the country. For example, between 1960 and 1964, the Appalachian region accounted for 715 of 1,106 reported cases (Weinburgh, 1966).

The disease proves to be fatal on an average of 20% of the time in untreated cases. However, the range of percent fatalities will vary from 5 to 80 in untreated cases, in that there are different strains of <u>Rickettsia rickettsii</u> each demonstrating different degrees of virulence (Weinburgh, 1966).

Description of Disease and Pathology

At present, the only known natural means of transmission of Rocky Mountain spotted fever to man is through an infected tick (Cox, 1962). The tick itself shows little or no ill effects from Rickettsia rickettsii (Grissom, 1971). However, once the rickettsae finds its way to a human host, it can become a serious medical problem; so much so that Rocky Mountain spotted fever has been described as being one of the most severe of all infections (Rosenblum et al., 1952 in Cox, 1959).

The causitive agent penetrates the endothelial cells of blood vessels and enters the nuclei causing destruction of the cells. The escaping rickettsae enter the blood stream and perivascular tissues spreading to other points of the body. The resulting infiltration can lead to gangrene (Craig and Faust, 1970). The damage done to the skin, subcutaneous tissues, and the brain is greater due to Rocky Mountain spotted fever than any of the other rickettsial diseases (Cox, 1959 in Weinburgh, 1966). Further, in some cases, the residual damage caused by Rocky Mountain spotted fever may linger for one year or more and may ultimately be considered permanent (Rosenblum et al., 1952 in Cox, 1959).

The disease requires an incubation period of two to five days in severe cases, two to 14 days in the less severe cases (Craig and Faust, 1970). Fevers of 104° F to 105° F or higher are common, and generally do not fall until the end of the 3rd week, or until the end of the 2nd week in mild cases (Cox, 1959).

The rash caused by Rocky Mountain spotted fever may be confused with that of other unrelated as well as related diseases, as measles, meningococcal meningitis, scarlet fever, smallpox, typhoid fever, septicemic conditions, certain drug rashes, rickettsial pox and murine typhus (Cox, 1959).

Incidence of Rocky Mountain Spotted Fever

During the height of prevalence of Rocky Mountain spotted fever within the Bitter Root Valley of western Montana, the fatality rate for nonvaccinated adults averaged approximately 80%, while that of nonvaccinated children was approximately 37.5%. Overall the disease being more severe in patients over 40 years old (Cox, 1959). However, as stated earlier, the average for fatalities is 20% in untreated cases. With the introduction of antibiotic treatment, the average fatality declined to the vicinity of 6% (Weinburgh, 1966).

It was at one time felt that Rocky Mountain spotted fever caused more fatalities in the west than in the east. Topping (1941 in Weinburgh, 1966) investigated this concept by comparing data from two western states, Idaho and Montana, with data from two eastern states, Maryland and Virginia. From 1930-1939 inclusive, the western states had 747 reported cases of Rocky Mountain spotted fever with 210 deaths, resulting in a fatality rate of 28.1%. The eastern states (data for Virginia was for 1933-1939 inclusive) reported 661 cases with 122 deaths, for a fatality rate of 18.4%. In the western states, 14.4% of the reported total were patients under 15 years of age, while 46.8% of the cases within the eastern states were patients under 15 years. For the 15-39 age group, the western states had 35.3% of

their total reported cases, the eastern states having 28.5%. Finally, for the 40 year old and over age category, the western states showed 50.2% of the reported total, the eastern states 24.5%. Topping showed that of the total reported cases, 83.5% were male and 16.5% were female for the west, while 60.6% were male and 29.4% were female for the east.

The higher incidence of infection in women and children in the east as compared to the west may be explained by the prevalent tick vectors found in the two different sections of the country. Dermacentor andersoni is the tick generally regarded as responsible for Rocky Mountain spotted fever in the western states. This tick in generally found in areas away from human habitation, thus persons exposed to the tick would be those persons who enter rural and wilderness areas either due to their profession or for recreation. The tick generally thought to be responsible for Rocky Mountain spotted fever in the eastern states in D. variabilis, the American dog tick. This tick is commonly found in areas of human habitation. D. andersoni is less likely to be found in areas of human habitation in that the adult is more readily, though not exclusively, found on larger mammals, while the adult of D. variabilis is found primarily on dogs, though it will parasitize a host of other mammals.

During the years 1960-1964, 1,106 cases of Rocky Mountain spotted fever were reported for a yearly average of 221 cases. For this same time period, 82 cases were reported from the mountain states, while 715 cases were reported from the Appalachian states. The national average of reported cases for 1960-1964 was one case per

million population with the average rising to 1.5 cases per million population for 1964. Twelve states reported an incidence greater than twice the national average; these states being Colorado, Idaho, Montana, Wyoming, Oklahoma, Delaware, District of Columbia, Georgia, Maryland, North Carolina, Tennessee, and Virginia (Weinburgh, 1966).

In 1968, there were 298 reported cases of Rocky Mountain spotted fever in the United States, followed by a rise of 200 cases for a total of 498 cases for 1969 (Peters, 1971).

For the first 15 weeks of 1972 (through the week ending April 15) there have been 19 cases reported to the Center for Disease Control, Atlanta, Georgia, as compared to seven reported cases for the first 15 weeks of 1971. For the 19 cases to date, the breakdown as to state is as follows: New Jersey - 1, Pennsylvania - 2, Kansas - 1, Virginia - 7, North Carolina - 1, South Carolina - 1, Tennessee - 1, Alabama - 1, Oklahoma - 2, Texas - 2.

Possible Methods of Study Using Remote Sensing

If a pilot study is to be made of the Rocky Mountain spotted fever problem in the United States using remote sensing for the detection of the disease, extensive ground-truth data must be taken. It is suggested that an area of repeatedly high incidence is studied; Virginia being a primary choice.

Within the study state, various habitats should be extensively studied and compared as to vegetation present, terrain, and soil quality, and all factors which can be studied using remote sensing. These different habitats should include suburbian residential areas,

cultivated areas, areas of different stages of old-field succession, heavily and lightly wooded areas, fields and meadows. These areas should be studied for vegetation, terrain, soil, and the types and numbers of mammalian potential tick hosts present.

Further, the mammals should be live-trapped, and blood samples taken for laboratory testing for Rickettsia rickettsii, as well as being cleaned of any tick attached to its body. Ticks should be routinely collected, and also tested for the rickettsiae. (Ticks are readily drawn to a block of dry ice.) Once the data are collected, they can be compared with the data taken using remote sensing, such as color and color infrared photography and multipleband scanning.

With these data, it is possible that definite identifiable characteristics may be readily recognized using remote sensing, which relate to habitat maintaining suitably large populations of mammals and/or potentially infected ticks.

Conclusion

No definite correlation has been observed between actual numbers or ticks and the prevalence of Rocky Mountain spotted fever, the importance being rather on the numbers of ticks in an area which are infected with the rickettsiae. On this regard, generally less than 1% of the ticks in an area are infected with an infection rate of 5% of the ticks being considered very high (Weinburgh, 1966).

Regardless, Rocky Mountain spotted fever appears to be increasing steadily, hence maintaining itself as a definite health hazzard. The only present method of combating the disease is the vaccination

of people frequenting an area where they might contact the disease. Mammal control has not reduced the incidence of Rocky Mountain spotted fever in the past, as well as not being economically feasible (Weinburgh, 1966). Further, extensive mammal control would not be environmentally sound with the repercussions from such a project far outweighing any reduction in the disease. Tick control is possible on a limited scale, though not over extensive areas.

Rocky Mountain spotted fever is incidential in man, its normal hosts being ticks and other mammals. Though Rocky Mountain spotted fever is incidential in man, it can nevertheless be a highly virulent human disease and is worthy of further study.

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